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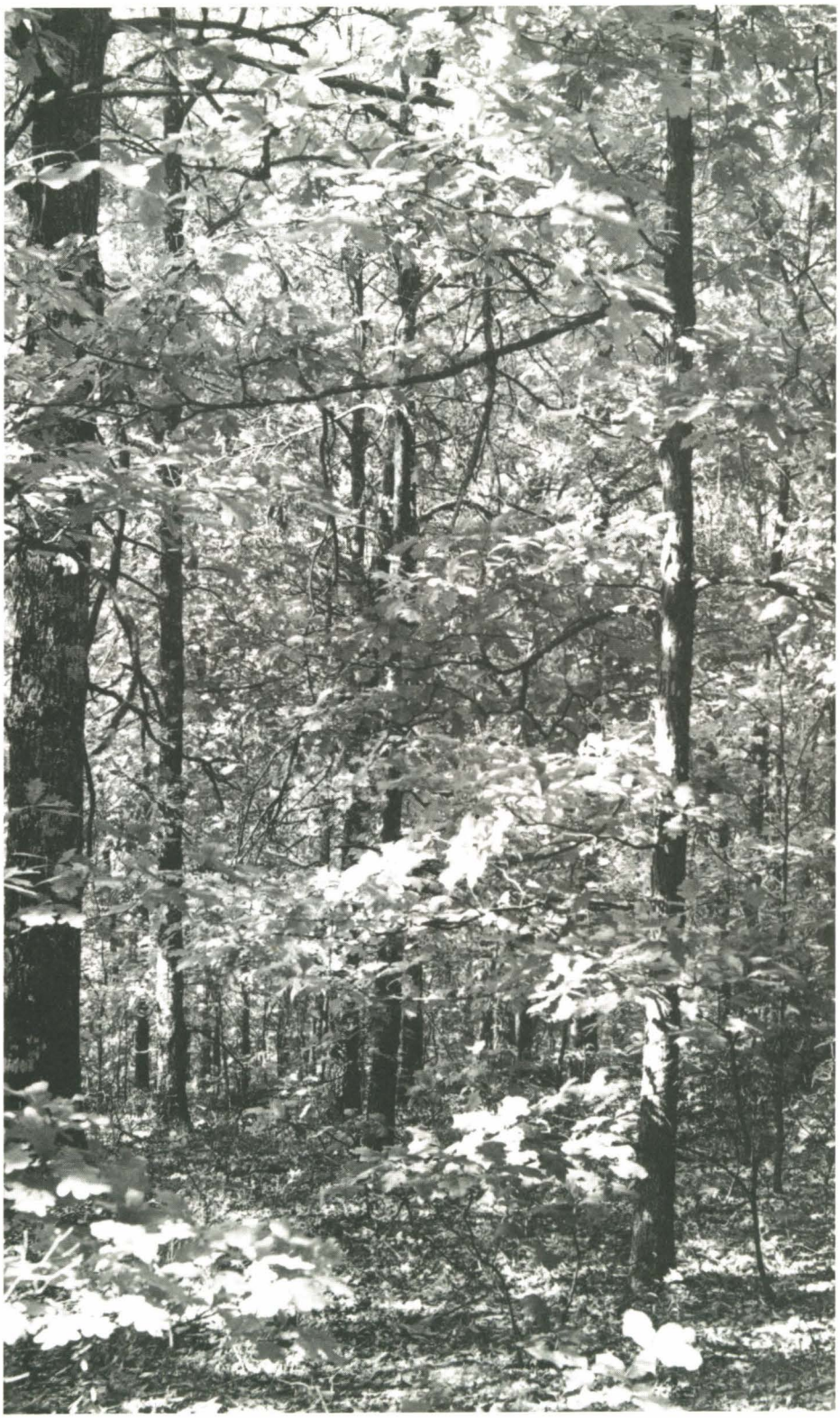
Oak

An American Wood

Oaks form the most important and abundant group of hardwood trees in North America and probably in the Northern Hemisphere. Collectively, the red and white oaks comprise 38 percent of the total hardwood volume in the United States. There are some 60 species and numerous hybrids, most of them east of the Great Plains. They are important producers of hardwood timber and veneers of excellent quality as well as outstanding beauty of grain and figure. Oak wood is strong, hard, and tough; has good working characteristics; and is used extensively for furniture, flooring, paneling, ties, and cooperage.



Oak
(*Quercus* L.)

Ivan L. Sander[1] and Howard N. Rosen[2]

Distribution

Oaks (*Quercus* spp.) are widely distributed throughout the Eastern United States and are an important source of wood and fiber. Although not every species occurs in every State, commercially important oak stands are found in all States east of the Great Plains. Northern red, white, and black oaks are the most widely distributed eastern oaks (fig. 1). The most commercially important western oaks are Oregon white oak and California black oak, but they occur only in the Pacific Coast States (fig. 2).

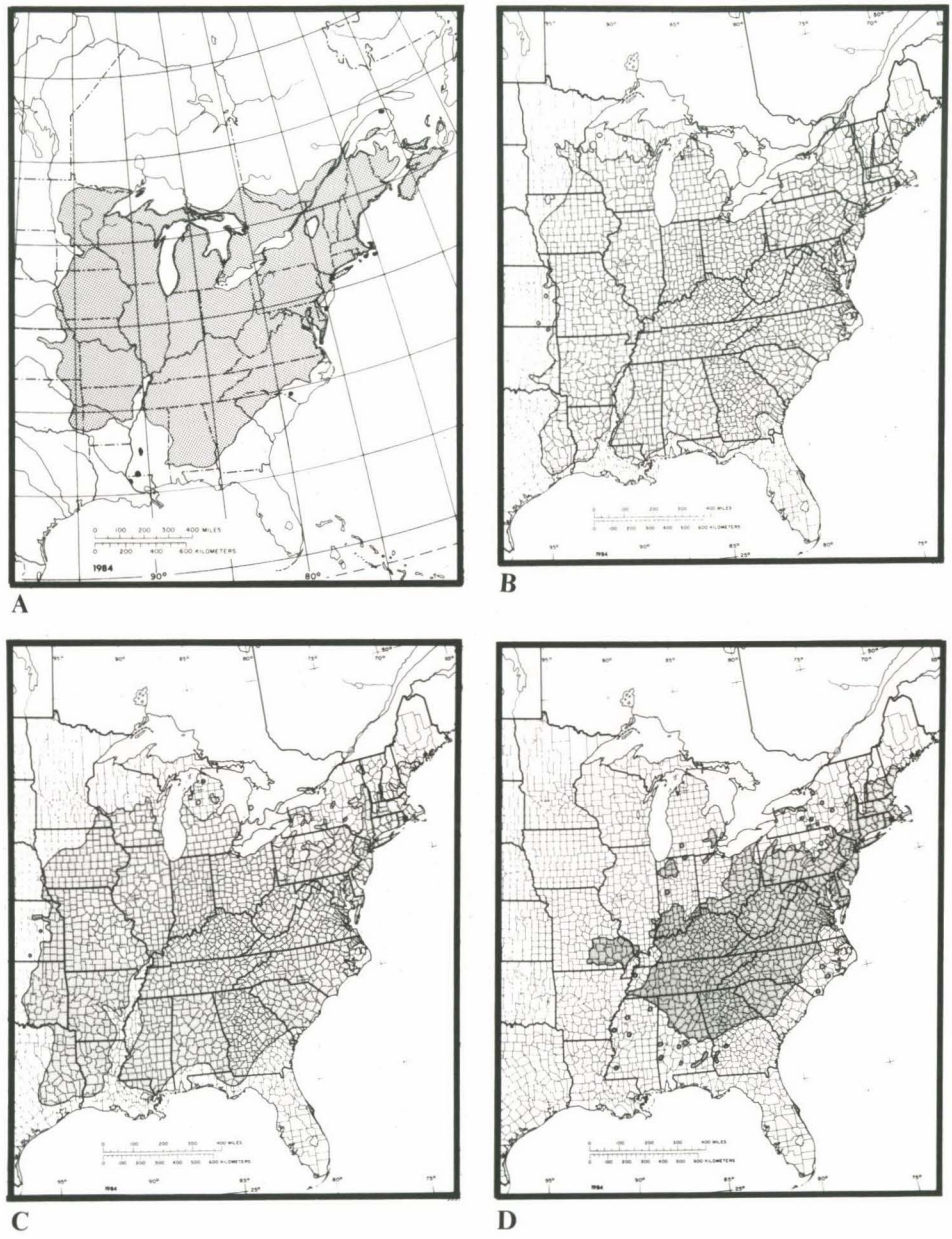


Figure 1—Natural range of (A) northern red oak, (B) white oak, (C) black oak, and (D) scarlet oak.

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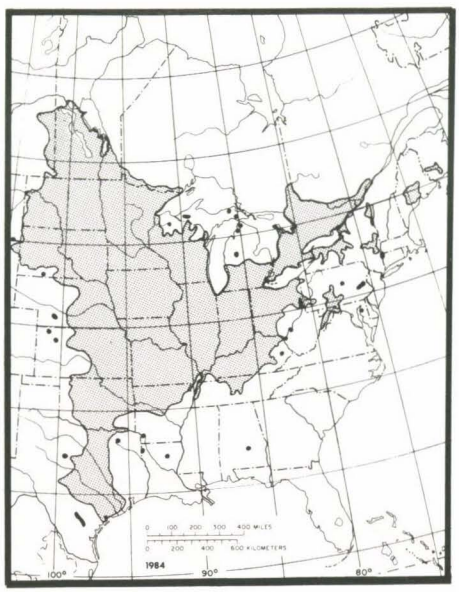

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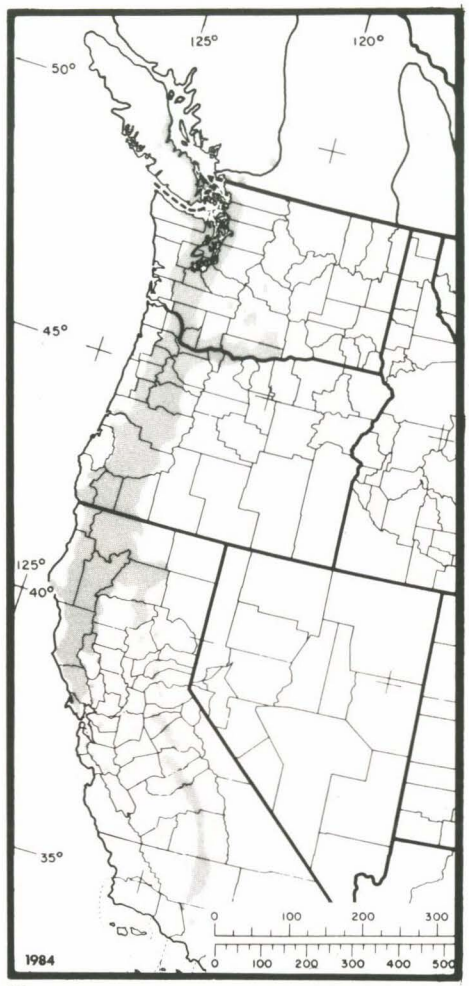

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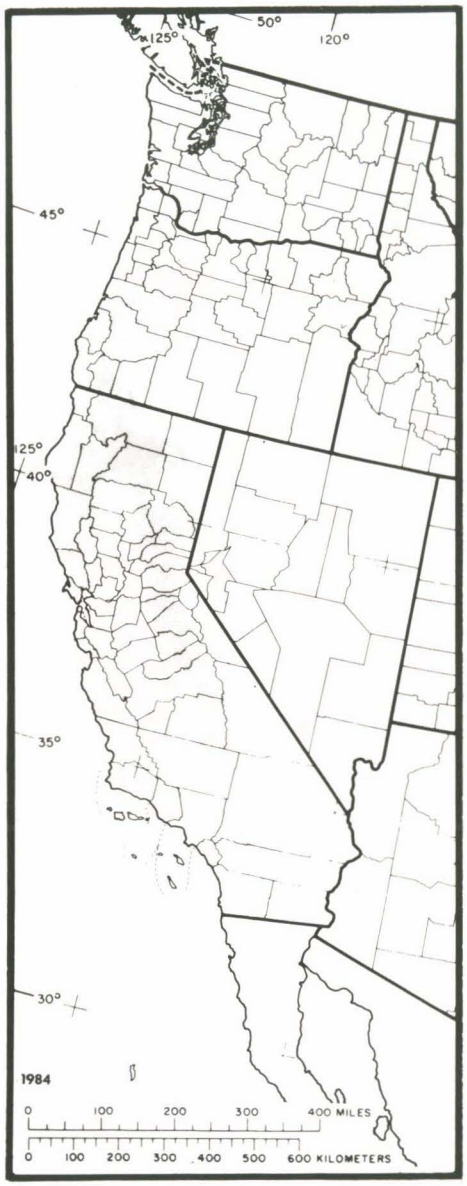

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Figure 2—Natural range of (A) bur oak, (B) Oregon white oak, and (C) California black oak.

Description and Growth

Botanically, oaks are divided into two main groups or subgenera—the white oaks, *Leucobalanus*, and the red oaks, *Erythrobalanus*. The white oaks have leaves that are lobed or coarsely toothed and do not have bristles at the end of the lobes or teeth (fig. 3). The acorns mature in the one growing season, are usually sweet, and germinate in the fall soon after they drop to the ground. The bark is usually light gray and somewhat scaly (fig. 4). In contrast red oaks have leaves that are lobed or have entire margins. Those with lobes have a bristle at the end of each lobe (fig. 5) while those with entire margins have a bristle at the leaf tip and may have bristles along the margin. The acorns require 2 years to mature, are usually bitter, and germinate in the spring following autumn seed fall. The bark is dark, usually furrowed, and often blocky (fig. 6).

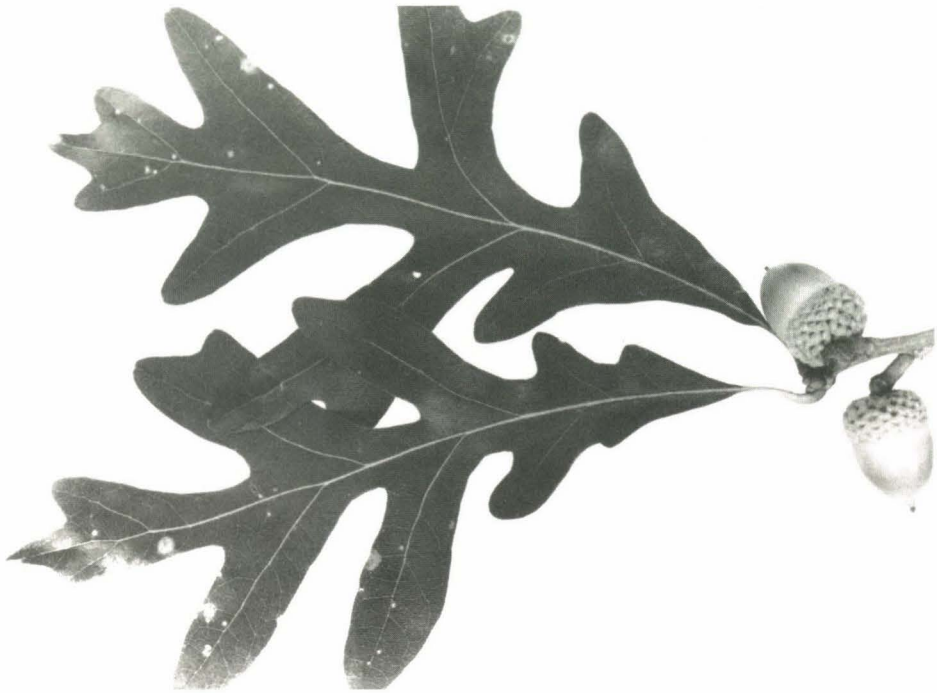

Figure 3—White oak (*Q. alba*) leaves, twig, and acorns.

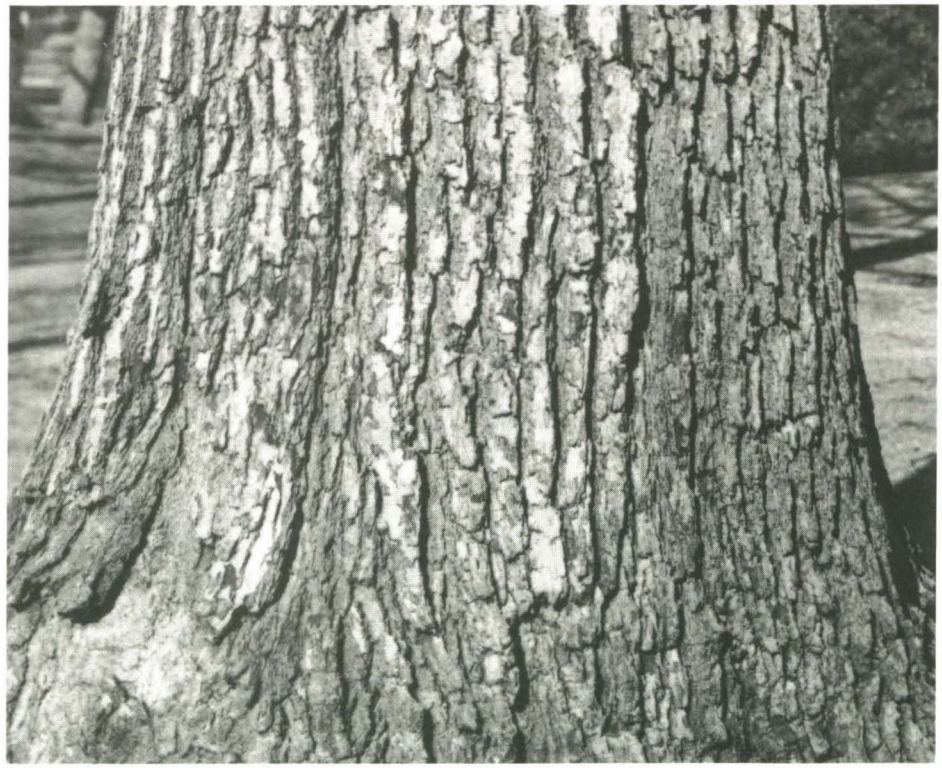

Figure 4—White oak (*Q. alba*) bark.

Both male and female oak flowers are borne on the same tree and appear in the spring when new growth begins. The male flowers are borne in yellowish-green catkins in the axils of the previous year's leaves. The tiny female flowers occur singly or in pairs in the axils of the newly developing leaves. Pollination is by wind.

Oaks generally occur in mixtures with other oaks and other species, both hardwoods and conifers. They grow on a wide range of soils and sites, from the wettest to the driest, from sea level to 5,000 feet or more in the Appalachian Mountains, and from north- and east-facing slopes to ridgetops and south- and west-facing slopes. Species that grow on sites that are often flooded for short periods, such as the first

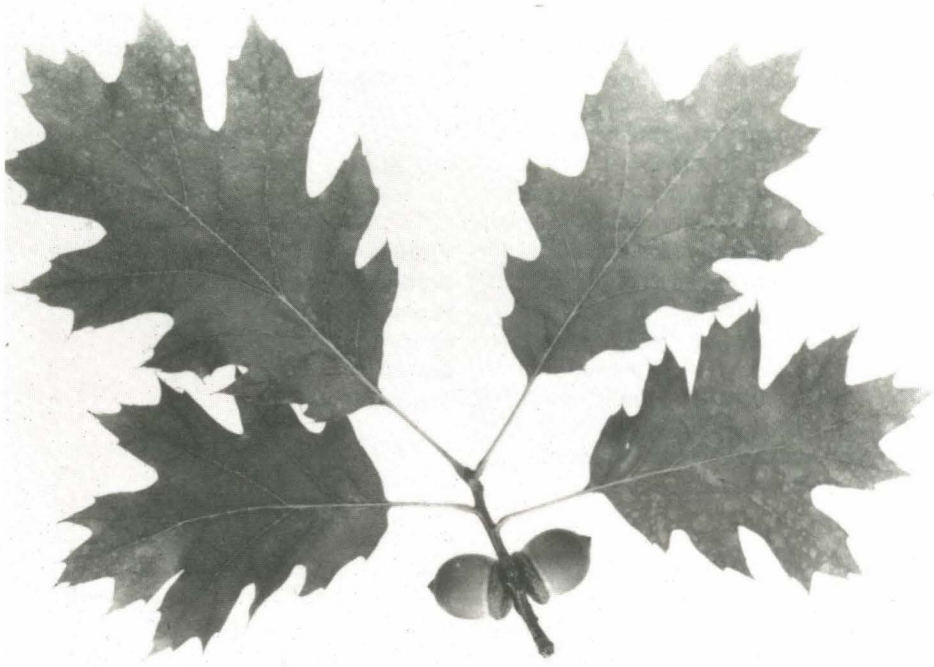

Figure 5—Northern red oak (*Q. rubra*) leaves, twig, and acorns.

Figure 6—Northern red oak (*Q. rubra*) bark.

bottoms and terraces along rivers and streams, include pin, water, willow, Nuttal, swamp white, overcup, swamp chestnut, cherrybark, and Shumbard oaks. Trees associated with them include silver maple, sycamore, sweetgum, sugarberry, pecan, green and black ash, American elm, and shellbark hickory.

Other oaks are found primarily on upland sites ranging from deep coves and well-drained valley floors to dry, rocky ridges. White, northern red, and black oaks are the most widespread; scarlet, chestnut, chinkapin, northern pin, southern red, post, and blackjack oaks also grow on these sites. Associated trees include pignut, shagbark, and bitternut hickories, black gum, yellow-poplar, white ash, elms, sugar and red maples, basswood, black cherry, and black walnut. On suitable sites, shortleaf, pitch, Virginia, and loblolly pine can also be found growing with the oaks.

Bur oaks grows on sites ranging from the moist to wet bottoms in the southern part of its range to the dry prairie fringes at its northwestern limits. Thus, it can be found associated with almost any of the species mentioned above.

Live oak grows in the south Atlantic and gulf coastal plains in association with southern magnolia, sweetbay, and American holly. Live oak with its shiny evergreen leaves and its widespreading branches is a favorite landscaping tree and is often picturesquely draped with Spanish moss.

Other oaks widely used for landscaping are willow oak, which because of its small leaves produces a delicate-appearing, lacy crown; and northern red, white, and pin oaks, which have large crowns and brilliant fall coloration.

The western California black oak and Oregon white oak are generally found

on dry sites with coarse-textured soils. Trees associated with them include ponderosa pine, Douglas-fir, incense cedar, knobcone pine, Pacific madrone, tanoak, bigleaf maple, Pacific dogwood, canyon live oak, and California laurel.

The growth rates of the various oak species are inherently different; species in the red oak group generally grow faster than those in the white oak group. Site quality also affects the growth rate with the fastest growth occuring on fertile sites well supplied with moisture.

Root systems will vary with the condition under which the species are growing. Generally, those species growing on wet bottom land soils or on soils with severely restricted internal drainage have a shallow root system, whereas those on drier and deeper soils develop taproots augmented by widely spreading surface roots.

All oaks sprout readily after the stem is killed, although sprouting ability decreases with increasing size and age of the stump. Thus, they are well able to survive fire, cutting, and other forces that kill the aboveground portion of the plant. Although their strong sprouting habit permits them to persist after burning, oaks can be seriously damaged by fires. The thin bark of all young stems, and also of some species such as laurel and live oak, is particularly susceptible to injury; but the bark even on old trees will be harmed by intense fires. Wounds from the fires will then permit entrance of insects and decay organisms, such as heartrot, so often found in mature stands.

Oaks produce good seed crops at irregular intervals of 4 to 7 years. A large proportion of the acorns are insect infested. Many mammals and birds seek them. Thus, abundant seedling reproduction is unlikely except after a bumper acorn crop. Early seedling growth is typically slow, in the range of 6 inches or less a year for the early years. In contrast, sprouts will often grow 3 to 6 feet a year for the first 2 or 3 years.

A number of fungi attack oak foliage, but the most serious disease is oak wilt, *Ceratocystis fagacearum*, which is widespread in the Central States and in some Eastern States. Trees of the red oak group are highly susceptible and are killed during the year of infection. Trees in the white oak group die over a period of several years. No control is practical, but fortunately the disease kills only scattered individuals or small groups of trees in a stand. It has not affected timber supply or lumber production.

A number of trunk-boring insects of the genera *Goes*, *Prionoxystus*, and *Romaleum* cause heavy losses in lumber quality by their larval tunnels in the trunk. Oaks are a favored host of the gypsy moth, *Porthetria dispar*, a serious defoliator. Repeated defoliation kills trees, and damage is widespread in the Northeastern States.

Common Names

All oaks species have several common names, but only the preferred ones are listed, and local usage may differ from these (tables 1 and 2).

Related Commercial Species

All oak lumber and wood products are bought and sold as either red oak or white oak. The subgenus of the species determines which name is used; once the wood has been cut into products, individual species within a subgenus cannot be easily distinguished from each other.

Supply

Oaks, the principal hardwoods in the commercial forest land in the United States, constitute 9 percent of the total sawtimber volume and 38 percent of the hardwood sawtimber volume. Of the 224 billion board feet of oak sawtimber, 42 percent is located in the following six States.

State	Net volume (Billion board feet)	Percent of Total
Virginia	19.6	9
North Carolina	16.6	7
Pennsylvania	15.4	7
Georgia	14.9	7
Kentucky	14.1	6
Tennessee	13.8	6

In 1977, the total United States growing stock was 49 billion cubic feet of red oak and 39 billion cubic feet of white oak. More than 97 percent of oak growing stock was located in the Eastern United States. Of this material, 41 percent was in trees from 5 to 11 inches in diameter at 4.5 feet above the ground, 32 percent was in trees more than 15 inches in diameter, and only 9 percent was in trees more than 21 inches in diameter.

At present, oak growth exceeds the cut; however, the excess growth is mostly in small trees. In 1976, the net annual growth of growing stock was 3.5 billion cubic feet, more than twice the removal, whereas the net annual growth of sawtimber was 9.5 billion board feet, only 66 percent more than the removal. From 1952 to 1976, trees 15 inches and larger in diameter, which are the backbone of the hardwood industry, decreased 35 percent. Although the trees larger in diameter have been overcut, many more large trees will become available as current stands, which have a surplus of smaller trees, grow older. However, a large proportion of oak stands in the Eastern United States are too young to contain many large trees. Also, many of the smaller trees could be harvested in intermediate cuttings that would benefit the remaining stand.

Table 1—*Characteristics of important white oak species*

Scientific name	Preferred name	Growth characteristics	Leaf description	Acorn
Q. alba L.	White oak	Large tree commonly 100 feet tall, straight boled, found on variety of soils and sites.	Deciduous, 5–9'' long, 2–4'' wide, 7–9 deeply or shallowly lobed, bright green above, paler below.	3/4'' long, bowl-like cup with warty scales.
Q. bicolor Willd.	Swamp white oak	Medium-sized tree, 70–80 feet tall, typical of lowlands, swamp edges, and wet flats.	Deciduous, 5–6″ long, 2–4'' wide, coarsely toothed or irregularly shallowly lobed, shiny dark green above, paler and pubescent below.	1'' long, borne on long stalk, enclosed 1/3 in slightly fringed cup.
Q. garryana Dougl. ex Hook.	Oregon white oak	Medium-sized tree, 50–70 feet tall, best growth on deep loamy soils in valleys and lower slopes of Cascade and Siskiyou Mountains of Oregon and California.	Deciduous, 4–6'' long, 2–5'' wide, 5–7 rounded lobes, shiny dark green above, paler below with orange-brown pubescence.	1–1¼'' long, shallowly encased in bowl-like cup.
Q. lyrata Walt.	Overcup oak	Medium-sized tree, typically 80 feet tall, growing on lower poorly drained first bottoms and terraces.	Deciduous, 6–10'' long, 1–4'' wide, with 5–9 irregular lobes, dark green and smooth above, green and nearly smooth or silvery white and downy below.	3/4'' nearly round, nearly enclosed by deep, unfringed cup.
Q. macrocarpa Michx.	Bur oak	Large tree on better sites, often 100 feet tall, frequently on dry thin soils, intruding into dry prairies but also in moist bottoms of Midwest.	Deciduous, 6–12'' long, 3–6'' wide, with 5–9 lobes, two deep center recesses, dark green shiny above, pale and pubescent below.	3/4–1½'' rounded, half enclosed in deep fringed cup, usually stalked.
Q. michauxii	Swamp chestnut oak	Medium-sized tree 60–80 feet tall on well-drained terraces and first bottom ridges of large and small streams.	Deciduous, 5–8'' long, 3–4 1/2'' wide, broadly obovate, coarsely toothed, dark green and shiny above, silvery white and pubescent below.	1¼'' long, not more than 1/3 enclosed in thick cup with wedge-shaped scales.
Q. muehlenbergii Engelm.	Chinkapin oak	Medium-sized tree 60–80 feet tall, associated with well-drained dry sites on limestone formations.	Deciduous, 4–7'' long, 1–4'' wide, coarsely toothed, yellow-green glabrous above, pale and finely pubescent below.	3/4'' long, half enclosed in thin cup, dark brown to nearly black.
Q. prinus L.	Chestnut oak	Medium-sized tree 60–70 feet tall, typically on dry sandy or gravelly soils but is found in coves and well-drained bottoms.	Deciduous; 4–8''long, 1½ to 3'' wide, coarsely toothed, yellowish-green and shiny above, paler and often finely pubescent below.	1'' long, 1/3 to 1/2 enclosed in thin cup, borne on a stalk.
Q. stellata Wangenh.	Post oak	Small to medium-sized tree, 30–60 feet tall, depending on site. Typical of dry rocky ridges, gravels, and sands, also of heavy soils, that are alternately waterlogged and hard and dry.	Deciduous, leathery, 4–6'' long, 3–4'' wide, 5-lobed, with crucifix shape, dark green above, pale green and hairy below	1/2'' long, sometimes striped, enclosed 1/3 of length in cup with thin scales.
Q. virginiana Mill.	Live oak	Medium-sized tree from 40–60 feet tall, nearly always on deep sandy soils. Highly resistant to salt spray.	Evergreen, drooping after new leaves appear in the spring, 3–5'' long, 1/2 to 2½'' wide, edges smooth and slightly rolled under, dark glossy green above, grey-green and densely hairy below.	3/4–1'' long, borne on stalk in clusters of 3–5, dark brown to nearly black, 1/3–1/2 enclosed in cup.

Table 2—*Characteristics of important red oak species*

Scientific name	Preferred name	Growth characteristics	Leaf description	Acorn
Q. coccinea Muenchh.	Scarlet oak	Medium to large tree, occasionally 100 feet tall, short-boled, found on dry sandy soils.	Deciduous, 4–7'' long, 3–5'' wide; deeply 7–9 lobed, shiny green above, paler below.	1/2–1'' long; 1/3 to 1/2 enclosed in bowl-like cup.
Q. falcata Michx.	Southern red oak	Medium-size tree, 70–80 feet tall, with short trunk and extensive rounded crown, typically found on dry poorer soils of uplands and ridges.	Deciduous, 5–9'' long, 4–5 wide, 5–11 narrow uniform lobes, dark green and shiny above, paler and hairy below.	1/2'' long; sometimes with fine lines and star-shaped hairs, enclosed 1/3 or less in shallow cup.
Q. falcata var. *pagodifolia* Ell.	Cherrybark oak	Large tree, 80–120 feet tall with long massive trunk, found on rich bottom lands and old fields.	Deciduous, 5–9'' long, 4–5'' wide, 5–11 narrow uniform lobes, dark green and shiny above, paler and hairy below.	1/2'' long, cup enclosing about half of nut.
Q. kelloggii Newb.	California black oak	Medium-sized tree 50–60 feet tall. Found in Pacific Coast States on dry gravelly or sandy soils or canyon floors, benches, or mountain slopes.	Deciduous, 3–5'' long, 5–7 lobes dark yellow-green above, paler and often hairy below.	1'' long, enclosed 1/3 to 2/3 in bowl-like cup with toothed scales.
Q. nigra L.	Water oak	Medium-sized tree, but will frequently reach 100 feet, straight slender trunk, grows best in moist alluvial bottom land soils but seldom in permanent swamps.	Deciduous, although some leaves persist until late winter, spatulate, 2–4'' long, 1–2'' wide, 3-lobed at tip or sometimes 5-lobed, dull blue-green above, paler below.	1/2'' long, hemispherical, nearly black, often with fine lines, enclosed at base with thin saucer-like cup.
Q. nuttallii Palmer	Nuttall oak	Medium to large tree, frequently reaches 100 feet, straight cylindrical bole, found on heavy, poorly drained clayey soils in first bottoms of major rivers.	Deciduous, 4–8'' long; 2–5'' wide, 5–7 lobes, dark green above, paler below with tufts of hairs in vein junctions.	3/4 to 1¼'' long, often with fine lines, 1/4–1/2 enclosed in a stalked, scaly cup.
Q. palustris Muenchh.	Pin oak	Large tree, 70–90 feet tall (up to 120 on best sites), found on wet sites of stream bottom, often on heavy poorly drained soils.	Deciduous, 3–5'' long, 2–5'' wide, deeply 5–7 lobed, dark shiny green above, paler below with tufts of hair at vein junctions.	1/2'' long, often with dark lines, enclosed only at base in thin cup.
Q. phellos L.	Willow oak	Medium to large tree up to 120 feet tall, with straight tall trunk, characteristic of wet stream bottoms.	Deciduous, 2–5'' long, 1/3–1'' wide, margin smooth, light green and shiny above, paler below.	1/2'' long or less; somewhat hairy, enclosed at base by thin cup.
Q. rubra L.	Northern red oak	Medium-sized tree about 70 feet tall, but may reach more than 100 feet with a tall columnar bole free of branches; typically found on deep soils on cool slopes and coves.	Deciduous, 5–8'' long, 4–5'' wide, regularly 7–11 lobed, dark green and smooth above, paler below with occasional tufts of hair at vein junctions.	1/2'' long, hairy towards apex, cup variable from saucer shaped to deep and enclosing 1/3 of acorn.
Q. shumardii Buckl.	Shumard oak	Large tree, 90–125 feet and taller with long clear bole, commonly found on well-drained bluffs and stream terraces although found on drier sites at western and northern edges of its range.	Deciduous, 6–8'' long, 4–5'' wide, 7–9 lobes often again divided with many bristle tips, dark green and shiny above, paler below.	3/4 to 1¼'' long, tapering slightly to tip, 1/4 enclosed by thick saucer-shaped cup.
Q. velutina Lam.	Black oak	Large tree generally not more than 80 feet tall but may reach 150 feet, typically growing on dry sandy or rocky ridges or heavy hillside clays.	Deciduous, 5–7'' long, 3–5'' wide, 5–7 toothed and bristle-tipped lobes; dark shiny green above, hairy and yellow green to coppery below.	1/2–3/4'' long, often with dark lines, 1/4 to 1/3 enclosed in a bowl-like cup.

Production

Oak lumber production has changed greatly over the years in response to changing technology and need. Lumber production peaked at 4.5 billion board feet in 1899 (fig. 7). Because of the decreased availability of Eastern oaks and the increased availability of west coast softwoods, oak use gradually declined to 0.6 billion board feet in 1933. Greater consumer demand for furniture, flooring, and other products made from oak lumber caused a gradual production rise into the late 1950's, followed by a pattern of moderate dips and increases. In 1955, oak lumber production in the Eastern United States was an estimated 3.7 billion board feet; it has not reached that level since. The 1980 production of oak was 3.2 billion board feet.

The production of oak is increasing in forms other than lumber. In 1980, oak was used for 44 percent of all the treated railroad crossties in the United States—more than 12 million ties. Tie production bottomed out in the early 1960's because of a decline in railway mileage, increased tie life, and deferred maintenance. However, tie production increased then leveled off in the late 1970's.

The production of oak bolts used for hardwood dimension and cooperage and the peeling of oak veneer logs for furniture, container, and plywood increased from 1940 to 1980. Since the development of improved pulping methods, oak manufacturing residues and low-grade stems not suitable for lumber have been increasingly used for pulp production. More complete wood utilization, especially of manufacturing residues, is one of the goals of the hardwood industry.

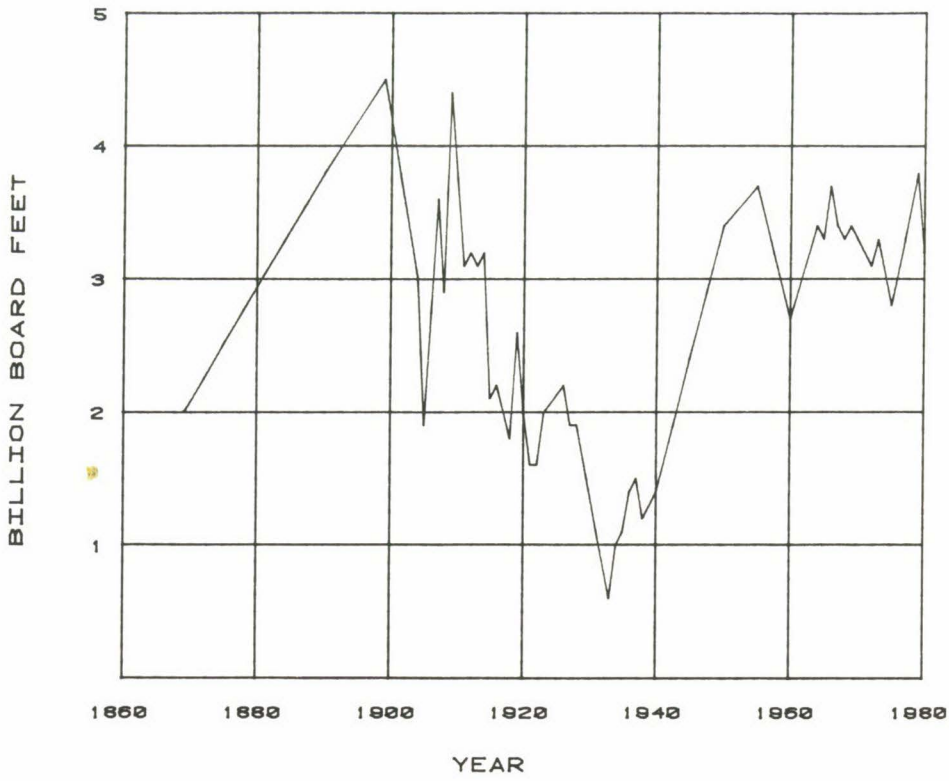

Figure 7—Oak lumber production.

Characteristics and Properties

The various species of oak cannot be positively identified from their wood alone, but usually a specimen can be discerned as belonging to the red or white oak group by the heartwood color, presence or absence of tyloses (membranous growths in pores of the heartwood), and the size and arrangement of latewood pores. White oak heartwood ranges in color from light or grayish brown to dark brown. Red oak heartwood has a characteristic red tinge. In both groups the sapwood is almost white to very light brown and ranges from 1 to 2 inches or more in thickness.

Oak growth rings are very distinct (figs. 8 and 9). The wood is referred to as ring-porous. The clearly visible earlywood pores form early in a growing season and are much larger than those of the latewood. These large pores give the oak its coarse texture. The pores in the white oaks, except in the outer sapwood, are usually plugged by the frothy-appearing tyloses (fig. 8). These pore-plugs make white oaks impermeable. Red oaks typically do not have tyloses (fig. 9). The latewood pores vary in size and arrangement between the two subgroups, providing the best means for identifying their woods. A hand lens can be used to examine a smooth cut on the end grain. If the latewood pores are clearly visible as round solitary openings, the wood belongs to the red oak group; if they are small, angular, and in bunches, the wood belongs to the white oak group.

Broad wood rays show as light-colored radial lines on the end grain and as dark-colored distinct flakes or ribbons on the quartersawn faces. These often give the wood a striking figure. The rays are generally higher along the

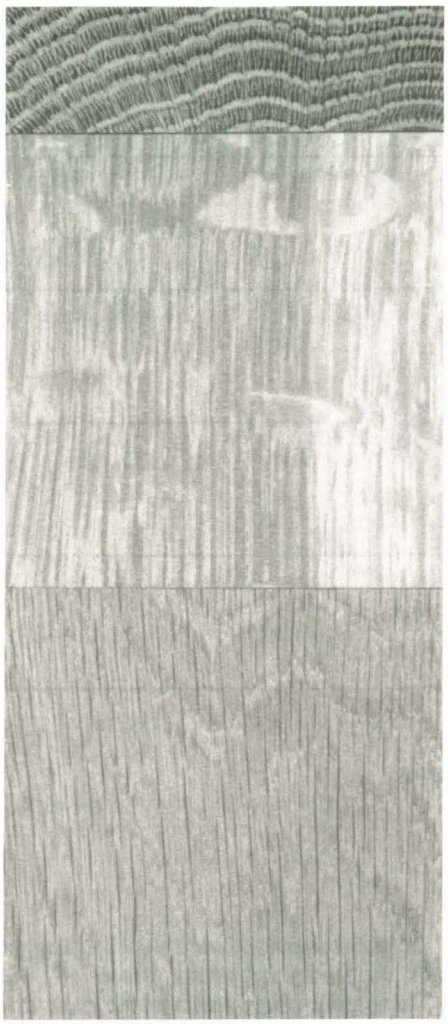

Figure 8—White oak. In the transverse view (top) the light wavy bands are the earlywood pores at the beginning of each annual ring and the rays are straight lines crossing them at right angles, resembling radii. The pores are mostly plugged with tyloses. On the right edge of the radial section (center) the ray flecks are visible as crescents and ribbons. The tangential view (bottom) shows the wavy pattern of the annual rings.

Figure 9—Red oak. The transverse section (top) shows the open pores without tyloses (compare to figure 8). The radial face (center) shows bands and flecks produced by the large wood rays. At the bottom is the tangential section.

grain in the white oak than in red oak—the larger ones in white oak may be as much as 5 inches high and are generally one-half of an inch high. The wood rays in red oak are generally less than 1 inch high and average about one-half of an inch.

The oaks are relatively heavy woods. At 12 percent moisture content, white oaks average about 47 pounds per cubic foot. Specific gravity, based on green volume and ovendry weights, ranges from 0.57 to 0.64 for white oaks and from 0.52 to 0.61 for red oaks. Oak is usually straight-grained, hard, tough, very stiff, and strong. Although the wood from individual oak species differs somewhat in strength properties, white oak wood and red oak wood generally have about the same strength properties. Fast-grown oak that has wide growth rings is stronger and heavier than slow-grown oak.

Oak has long been a favorite wood because of its good working characteristics. It machines and glues well and holds fasteners exceptionally well. However, it tends to split when nailed, and predrilling pilot nail holes is a common practice to avoid splitting. Oak also finishes well, and because it has coarse grain, a variety of color effects are possible by changing the filler applied to the pores before the lacquer or varnish finish.

Oak wood tends to shrink greatly, and it must be dried more slowly than many other hardwoods. Drying too quickly in a kiln can cause end and surface checking, honeycombing, and collapse, particularly in 2-inch and thicker lumber. Properly controlled kiln drying minimizes drying effects and improves the strength and working properties.

The heartwood of white oak has a high natural decay resistance, while that of red oak is rated as low. The white oaks cannot be readily impregnated with preservatives because of the tyloses, but this impermeability makes them highly valued for tight cooperage. Chestnut oak is an exception: it is a white oak, but generally does not have tyloses. The red oaks are low in decay resistance, but because they generally do not have tyloses, they are more easily penetrated and made durable with preservatives. Commercial oak lumber usually contains fewer, but larger, knots, than most softwood lumber. Much of the low-quality oak timber not good for lumber can be utilized for paper pulp. Oaks reduce readily to pulp, yielding about 45 percent sulfate or kraft pulp.

Principal Uses

Oak use has been closely tied to American history and changing technology. Because oak is durable and very strong, it was used extensively for shipbuilding until after the Civil War. In 1828, President John Quincy Adams set aside the Naval Live Oaks Plantation, the first forest land reserved by the U.S. Government, to conserve white and live oak for the large wooden sailing ships of that era. Oak use for shipbuilding diminished as the Navy shifted to steel; nevertheless, today about 4 million board feet, mostly white oak, is still used annually for shipbuilding and boatbuilding.

As the web of railroads grew across the Western United States, white oak was utilized to meet the demand for strong and durable ties. The less durable red oaks were also used but usually only after preservative treatment. Oak is still the leading wood used in tie production.

As Americans raised their standard of living, their need for products that utilized the strength, durability, and beauty of oak changed. During the settlement of the Middle Western States, white oak shingles and shakes were important products. Today they are only made by local artisans for special purposes. The use of oak for tannin dyes has almost ended, but its use for fuelwood has increased greatly in recent years. Tubs, railway cars, agricultural implements, nonmotor vehicles, and sporting goods formerly consumed much oak; however, substitute products and materials have now almost completely replaced oak. By far the greatest single use of oak today is for hardwood dimension and flooring. In 1977, more than 150 million board feet of oak flooring was produced. Oak furniture has always been popular, and in 1980 more than 200 million board feet of oak lumber was used in the furniture industry.

Oak is widely used as veneer and plywood in millwork and furniture. In one year, 1928, before the depression of the 1930's, about 7 million square feet of oak veneer and plywood were used for millwork and furniture. Today, annual consumption is more than 15 million square feet.

White oak continues to be the outstanding wood for tight barrels, kegs, and casks for storing and curing whiskey and wine. The flavor and quality of these beverages is improved by storage in oak barrels. No substitutes have been found that are as fully satisfactory. Oak is used in vehicles for truck and trailer beds because of its toughness and wear resistance. It is also extensively used for mining timbers, containers, pallets, caskets, boxes, and paneling.

Thus, in spite of substitutes and changing products, oak has been used in increasing quantities since 1948 because of its beauty, strength, and durability. And in 1980, nearly one-half of all hardwood lumber produced in the United States was oak.

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